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American Potato Journal

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EFFECT OF SIZE OF PLOT, EXPERIMENTAL DESIGN AND REPLICATION ON EFFICIENCY OF POTATO FERTILIZER EXPERIMENTS[1]

G. L. Terman, Mildred R. Covell and C. E. Cunningham[2]

Most of the potato soils of Aroostook County, Maine, tend to be quite variable, as are soils in most areas. Consequently, in field plot work on these soils it has been assumed that maximum control of soil variability is necessary for accurate results in potato experiments. Therefore it has been the practice for several years in potato fertilizer work in Maine to limit the number of fertilizer treatments in most experiments to 5-7 and randomize the treatments in Latin squares. Such designs, of course, give soil variability control in two directions.

Yield data from Latin square experiments on phosphorus and potash rates for potatoes conducted on Caribou loam and similar soils in 1946 were used to study the relative efficiency of various experiments and conditions within each experiment. No report of a similar study with potatoes was found in the literature.

Experimental Procedure

Field Technique

In 1946, phosphorus and potash rate tests were conducted on several farms in Aroostook County, Maine. Rates of P_2O_5 of 0, 40, 80, 120, 160, and 200 pounds per acre were compared in certain experiments, and K_2O rates of 0, 60, 120, 180, 240, and 300 pounds in others. In the P_2O_5 rate experiments a uniform application of 100 pounds N and 200 pounds K_2O was made to all plots; in the K_2O rate experiments a uniform application of 100 pounds N and 160 pounds P_2O_5 was made.

The Katahdin variety of potatoes was grown in all experiments. Rows were 34-35 inches apart and seed pieces were spaced 9 inches apart in the row. All experiments were 6 x 6 Latin squares, with 4 potato rows 50 feet long per plot. As indicated in figure 1, there were no border rows between plots, but plants in a 4-foot border between the ends of plots were removed to facilitate harvesting. Arrangement of the fertilizer treatments in a typical experiment is also shown in figure 1.

Each plot row was harvested and weighed separately and the weights converted to bushels per acre by the appropriate factor. In case of single missing hills, no yield adjustment was made; in case of 2 or more adjacent missing hills, 1 hill at each end of the blank space was dug prior to harvest and not included in the yield. The total blank space was then measured and the harvested row yield adjusted to the full length of 50 feet. As experiments selected for this study had relatively few missing hills, adjustments were small and few in number. No experiments were used in which yields for certain rows had been lost or appeared to be cut out of line because of unknown reasons. This was done in order to eliminate as much bias as possible from damaged rows or other causes not associated with the experimental design.

[1]Accepted for publication November 14, 1956.

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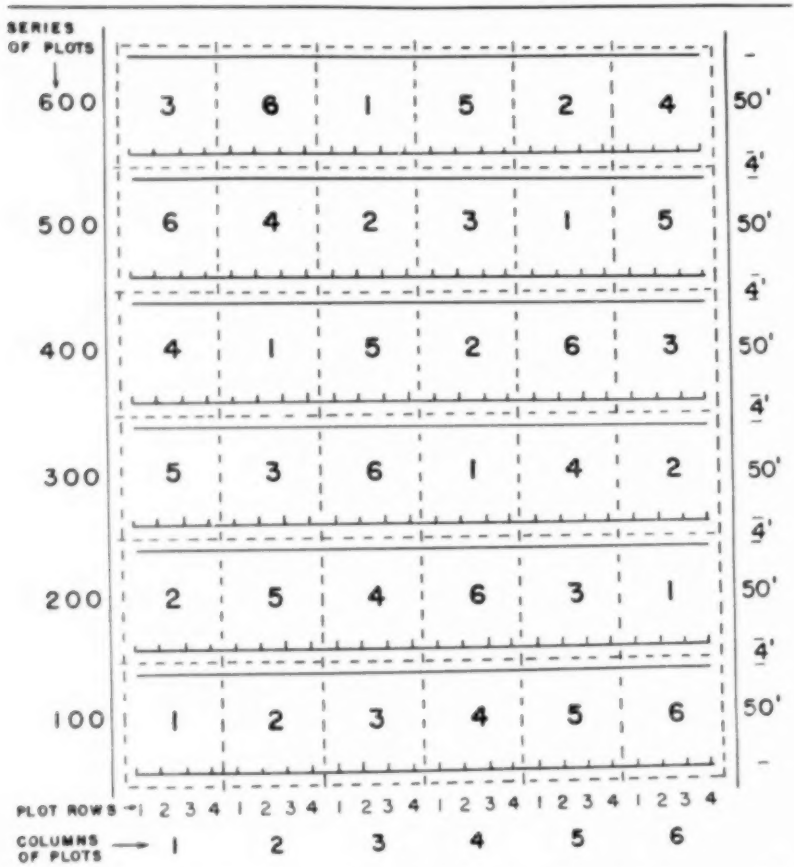

FIGURE 1.—Arrangement of plots and treatments in a typical 6 x 6 Latin square field fertilizer experiment. Treatment numbers 1-6 in plots correspond to 0, 40, 80, 120, 160, and 200 pounds P_2O_5 or 0, 60, 120, 180, 240, and 300 pounds K_2O in the fertilizer per acre, respectively.

STATISTICAL TECHNIQUE

Method A. Analyses of variance were made for the 6 x 6 Latin square experiments as follows for: Rows 1, 2, 3, or 4 separately; and Rows 2-3, 1-3, and 1-4 as 2-row groups. (See figure 1.) Analyses as randomized blocks were made for series (replicates) 100-200, 300-400, 500-600, 100-300, 100-400, 100-500, and 100-600. Columns of plots were also used as replicates. In addition, treatments in each experiment were assumed to be completely randomized, thus in the analyses both series and column variation were combined with experimental error.

From the error variance for each analysis a coefficient of variability (C.V.) was calculated:

$$\text{C.V.} = \frac{\sqrt{\text{error variance}}}{\text{mean of experiment}} \times 100$$

All mean C.V. values were based on the average of the individual error variance and experiment means. Because of the differences among these variances, the mean C.V. calculated in this manner differed slightly, in some cases, from the one obtained by getting the average of the individual C.V. values. From the C.V. values the relative precision (6)[3], or efficiency, of each condition, as compared with the 6 x 6 Latin square with 4-row plots, was determined. Since relative efficiency is defined as the inverse ratio of the error variances per unit, its value for Row 1 (or other condition), as compared to 4 rows per plot, is as follows:

$$\text{Relative Efficiency, or R.E.} = \frac{(\text{C.V.})^2 \text{ for 4 rows}}{(\text{C.V.})^2 \text{ for Row 1}} \times 100$$

R.E. values for various numbers of replicates were adjusted for differences in degrees of freedom according to the formula of Cochran and Cox (1, page 29). These values for series and column groupings of the 6 replicates were also adjusted according to the formula (1, page 112). All of these adjustments were small and did not appreciably affect the interpretation of results, as compared to unadjusted efficiency values.

Method B. The procedures used in method A to compare the efficiency of various numbers of rows per plot and replicates were based upon different parts of each experiment, which differed between parts in variability. The validity of such comparisons may have been open to question. Therefore, a second set of comparisons was calculated, using the technique employed by Rigney and Blaser (7). In this method, each individual row of the 4-row plots in a 6 x 6 Latin square design was treated as a unit in an analysis of variance. The estimated true variances due to plots and plot rows were obtained from their error mean squares. Then the variance of a treatment mean for each experiment was calculated as follows:

$$\text{Variance of treatment mean} = \frac{\text{Error variance (plots)}}{\text{No. of reps.}} + \frac{\text{Error variance (rows)}}{(\text{No. of reps.})\ (\text{No. of rows})}$$

Similarly, an analysis of variance was made of each experiment as a randomized block design with 6 replicates. Variance components of the experimental error were then calculated and combined for 6, 5, 4, 3, and 2 replicates. Calculations for various numbers of rows and replicates were also made. The same procedure was followed for each experiment, assuming rows of plots to be the replicates, and again for each experiment as a completely randomized design. Coefficients of variability were calculated from the variance for each treatment mean. For each complete experiment, these C.V. values were the same as calculated in Method A.

[3]Numbers in parenthesis refer to "Literature Cited".

Results of Fertilizer Treatments on Potatoes

Yield responses of potatoes to phosphorus and potash in the 6 experiments chosen for the statistical study are shown in table 1. Results of these additional experiments have been previously reported (2, 3). Significant differences at the 1 per cent level were obtained between phosphorus rates in all 3 experiments and between potash rates in 2 of the 3 experiments. Experiments which did not show significant differences between treatments at the 5 or 1 per cent levels were purposely avoided, so that the effects of plot size and replication on the differences necessary for significance between treatments could be studied. Appreciable yield response to fertilizer, especially to potash, was not obtained in all experiments.

Table 1.—*Response of Katahdin potatoes to phosphorus and potash in 4-row plot, 6 x 6 Latin square experiments.*

Phosphorus Rate Tests				Potash Rate Tests			
Fertilizer Treatment, 2000 Lbs. per Acre	Yield-Bus. per Acre			Fertilizer Treatment, 2000 Lbs. per Acre	Yield-Bus. per Acre		
	Bouchard Farm	Morgan Farm	Sides Farm		Cook Farm	Morgan Farm	Sides Farm
5-0-10	287	398	420	5-8-0	512	393	527
5-2-10	389	441	488	5-8-3	542	454	558
5-4-10	449	468	503	5-8-6	548	462	573
5-6-10	477	482	523	5-8-9	551	475	572
5-8-10	490	476	524	5-8-12	547	471	554
5-10-10	500	487	505	5-8-15	550	461	561
L.S.D.,				L.S.D.,			
5 per cent level	18	18	24	5 per cent level	24	32	24
1 per cent level	25	25	33	1 per cent level	N.S.	44	32
C.V.	3.5	3.3	4.1	C.V.	3.7	5.9	3.5

Variability in the 1946 Fertilizer Experiments

During the course of this study of variability in potato experiments, the question arose as to whether the coefficients of variability of the particular experiments selected for this study were not considerably lower than for most similar experiments which might be conducted. Or, in other words, were the results biased by the selection of experiments having only a very low plot variability? The 1946 experiments were selected for study because each plot row had been harvested and weighed separately. Most experiments in subsequent years were harvested in 2-row groups, because of the general use of 2-row diggers.

The coefficients of variability for the 6 Latin square experiments used in this study ranged from 3.3 to 5.9 per cent, whereas the coefficients of the remaining 11 experiments conducted in 1946 ranged from 2.8 to 10.5 per cent. One of the experiments not used in the study had a coefficient lower than the range of those used, 4 were in the same range, and 6 were

slightly higher. Thus, it may be seen that the results of the study were only slightly biased by the selection that was made.

Most of the coefficients of variability for the 1945 experiments (*2*) and for the 1946 experiments (*3*) were somewhat lower than has generally been reported for similar types of potato experiments. The reason for this was thought to be largely due to the yield levels obtained in the various experiments. Variability in the 1946 experiments, as indicated by the C.V. values, tended to decrease with increase in mean yield ($r = -.383$). Variability might, of course, be high or low at either high or low yield levels. With carefully selected sites of approximately the same soil differences over each plot area, however, C.V. values tended to decrease with increase in mean yield, as in the 1946 experiments.

Effect of Number of Rows Per Plot

As an average for the 6 experiments, coefficients of variability for 1, *2*, *3*, and 4-row plots 50 feet long were 5.77, 5.27, 5.18, and 4.05, respectively. These differences and the corresponding relative efficiency values are shown graphically in figure 2. Differences between treatments necessary for significance usually decreased in a similar manner with increase in number of rows per plot while relative efficiency values increased. Variability decreased with increasing number of rows per plot in 5 out of 6 experiments. This perhaps may be expected with a crop such as potatoes, which has a relatively small number of plants per plot.

Using the efficiency value for 4-row plots as 100, the average relative efficiency values for *3*, *2*, and 1-row plots in the 6 phosphorus and potash rate experiments were 61, 59, and 49 per cent, respectively. The C.V. and R. E. values indicate that variability would not be affected markedly by decreasing the number of rows per plot. Still less variability might be expected in the smaller area required for 1-row plots.

Coefficients of variability calculated for 4-row plots by methods A and B were the same in each experiment and for *3*, *2*, and 1-row plots only slightly different. Only in one potash test was the order for 4, *3*, *2*, and 1-row plots changed by method of calculation. This was due to considerable differences in the C.V. values between individual plot rows of the experiment. In general, the conclusions made from the *2* methods were the same.

The mean yield for each experiment, using 1 row or combinations of rows, usually varied from the mean for the 4-row plots by less than 10 bushels per acre. In no case was the variation more than 18 bushels, or about 4 per cent. Mean yields for the various fertilizer treatments varied somewhat with the various row combinations. Interpretation of the results, using *2* or 3-row plots, would have been similar to using 4-rows. However, significant differences obtained with 4-row plots were reduced to non-significance with 1-row plots. In general, *2* to 4-row plots were necessary to measure yield differences of less than 10 per cent of the mean yield.

As indicated in figure 1, there were no border rows between plots. In contrast to the results reported by Jacob (*4*), however, no effect of the fertilizer treatment for one plot was found on an adjacent plot. This was checked in 1950 by means of radioactive phosphorus, when no radioactivity

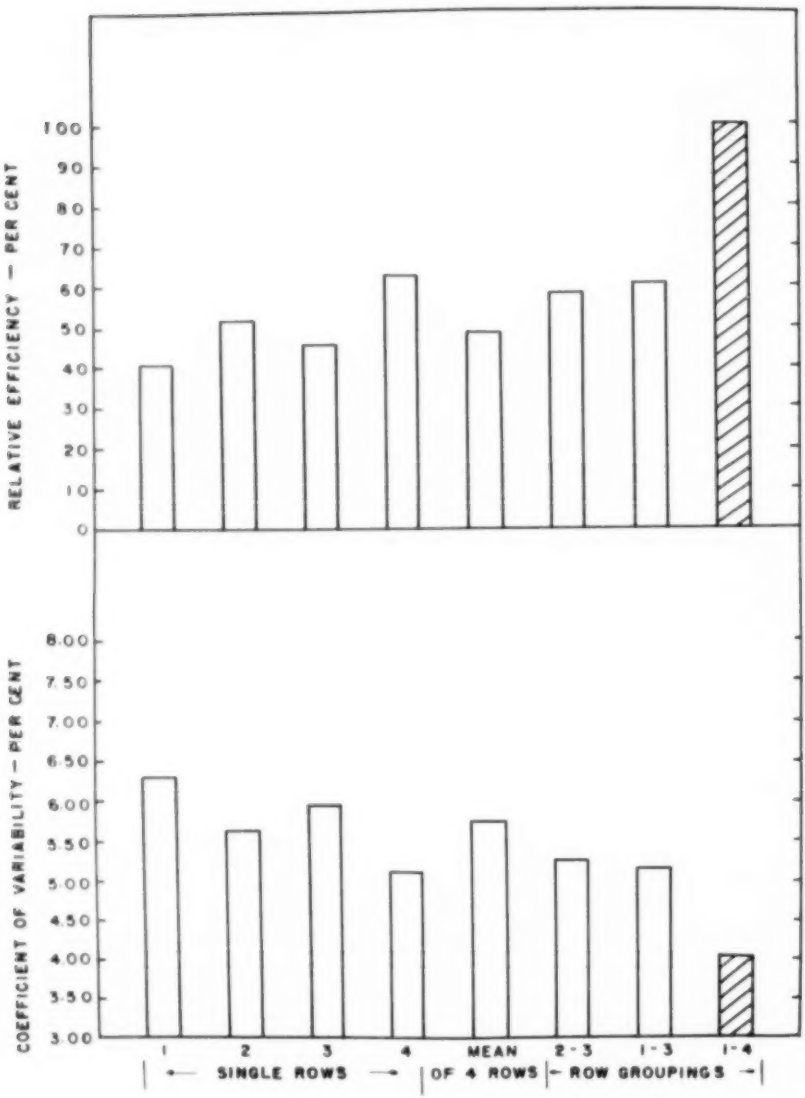

FIGURE 2.—Effect of number of rows 50 feet long per plot on variability and relative efficiency in 6 potato fertilizer experiments — 1946.

was detected in leaves of plants grown in rows adjacent to rows fertilized with radioactive phosphorus. Cross feeding between rows is probably largely prevented by the ridge-type of cultivation commonly practiced in Maine. The fact that the yields from outside plot rows were no more variable than inside plot rows also indicates that yields were not affected by cross feeding.

Effect of Type of Experimental Design

As indicated previously, the 6 fertilizer rate experiments were analyzed as 6 x 6 Latin squares, as randomized blocks with series and with rows of plots as the 6 replicates and as completely randomized designs. The analyses of variance were made by method A, in which totals of 4-row plots were used, and by method B, in which each 50-foot row was considered a unit.

Analyses of the experiments as randomized blocks with the 6 series of plots as replicates increased error variance thereby decreasing relative efficiency in 5 of the 6 tests. The exception was an experiment located on a very uniform test area. Analyses of the experiments as randomized blocks with the 6 columns of plots as replicates by method A increased error variance markedly. Mean C.V. values for the 6 experiments are shown graphically in figure 3. This increase in variability might be expected, since the blocks in this case consisted of 4 rows 320 feet long. In this case soil variability and spray wheel damage across the 24 rows was usually much less than soil variability between the 6 series of 50-foot rows over the 320-foot length of each experiment. Analyses as completely randomized experiments, in which both series and column variation were combined with experimental error, increased error variance still further in some experiments.

Effect of Number and Combination of Replicates

In analyses of variance of different numbers of replicates of each experiment as randomized blocks by method A, variability decreased on the average with increase from 2 to 4 replicates, but increased with further increase to 5 and 6 replicates. Mean C.V. values for 2, 3, 4, 5, and 6 replicates were 5.41, 4.52, 4.44, 4.77, and 5.26 per cent, respectively, as compared to 4.05 for analyses as 6 x 6 Latin squares. Corresponding relative efficiency values were 46, 71, 79, 71, and 60 per cent, respectively, as compared with 100 per cent for the Latin squares. Mean C.V. and relative efficiency values for the 6 experiments are shown graphically in figure 3. These replicates or blocks, as indicated in figure 1, consisted of 24 potato rows 50 feet long. Evidently in most experiments, extending the length of the experimental area more than 4 replications tended to increase soil variability to such an extent that the error variance was somewhat increased. An analysis of each entire experiment as Latin squares, however, usually resulted in the greatest precision.

Krantz (5) similarly found that variability in potato rows 4 rods long decreased with an increase varying from 1 to 4 replicates, and there was only a slight further decrease when the number of replicates was increased 5 to 7.

Variability of the potato fertilizer experiments, as shown by C.V. values calculated by method B, increased inversely as the square root of

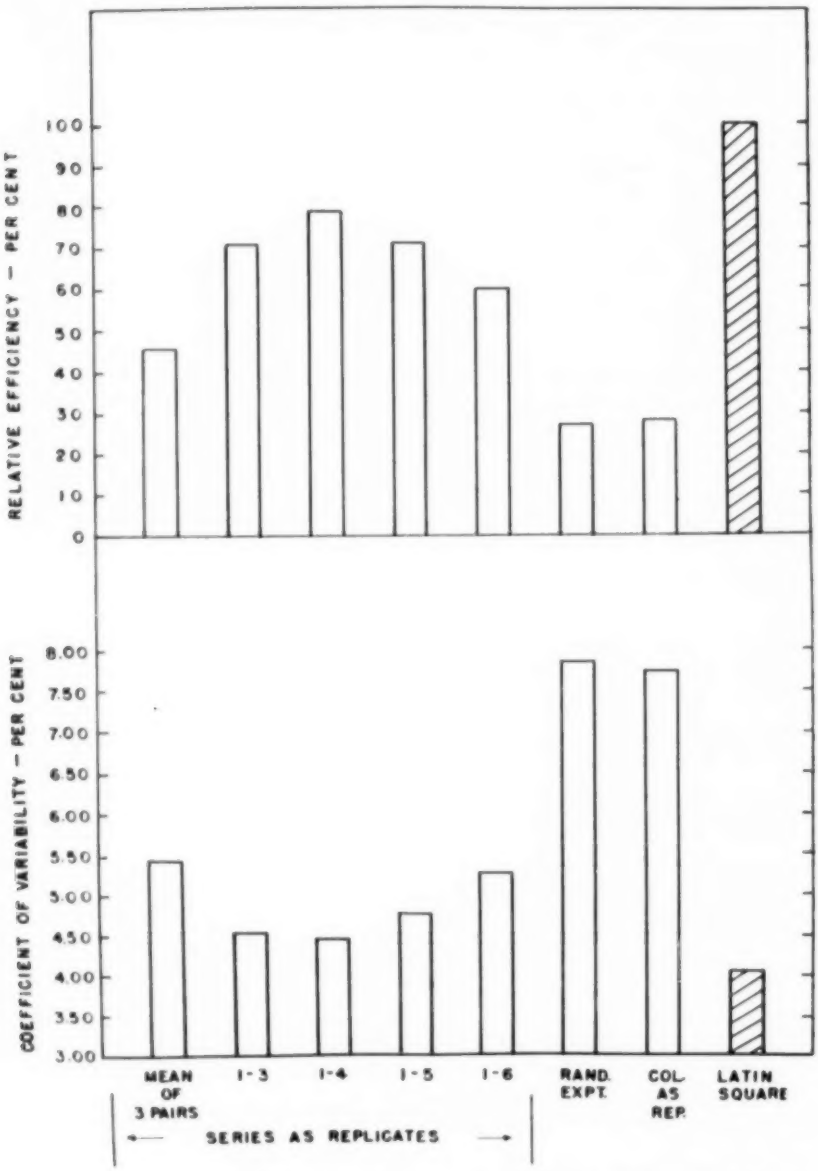

FIGURE 3.—Effect of number and combination of replicates on variability and relative efficiency in 6 potato fertilizer experiments — 1946.

the number of replications. This is thought to be true because of the variability in the Maine soil conditions under which these field experiments were conducted. Under more uniform soil conditions in certain other areas the assumption would undoubtedly be more valid.

In laying out experiments such as were analyzed in this study, a field diagram was first drawn up in the office. It was the tendency of those carrying out the field work according to the field plan to locate the first replicates (series 100 and 200 in figure 1) in a uniform area adjacent to a field roadway. Then, because of the frequent occurrence of knolls or depression areas in the field, other replicates tended to cut across these less uniform soil conditions. In 5 out of 6 experiments replicate pairs 5 and 6 were more variable than replicate pairs 1 and 2, and 3 and 4. The increase in variability for 5 or 6 replicates over 4 replicates, as shown in figure 3, is thought due to the particular field conditions of these experiments. It would be expected, however, that similar results would be obtained again under similar soil conditions.

C. V. values calculated by method B were not representative of the actual conditions of variability, as shown by analyses of pairs or other combinations of replicates. Coefficients of variability and relative efficiency values calculated by method A appeared to offer more valid estimates of the efficiency of different numbers of replicates in these experiments.

Summary

The effects of numbers of rows 50 feet long per plot, type of experimental design and number and combination of replicates in 6 potato fertilizer experiments were studied by means of analyses of variance and other statistical techniques. The experiments were conducted as 6 x 6 Latin squares in Aroostook County, Maine, in 1946.

Variability decreased with increase in the number of rows per plot from 1 to 4. Conversely, relative efficiency, or precision, was greater with increase in the number of rows per plot.

As compared to Latin square experiments, error variance increased, whereas relative efficiency decreased, when only columns of plots 4 rows wide and 320 feet long were used as replicates or when the experiments were assumed to be completely randomized. These values were changed much less on the average when only series, or blocks, of plots 24 rows wide and 50 feet long were used as replicates. Variability was portioned best and the precision greatest when the experiments were analyzed as Latin squares.

In analyses of the experiments as randomized blocks, with series of plots as replicates, variability decreased from 2 to 4 replicates, but increased from 4 to 5 replicates. Conversely, relative efficiency increased from 2 to 4 replicates, but became less from 4 to 5 or 6 replicates.

Four replicates of 4-row plots, because of the shorter distance and less soil variability involved, resulted in slightly greater efficiency on the average than did 6 x 6 Latin squares. Considering the experimental area and costs involved, 2-row plot experiments with 4 replicates would have been nearly as efficient as 6 x 6 Latin squares with 4-row plots and would have resulted in essentially the same amount of information.

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RUSHMORE, A NEW OBLONG BAKING TYPE POTATO[1]

Julian C. Miller[2]

The Rushmore potato is a cross between the Katahdin and Green Mountain varieties. This seedling has been grown under the code number 81-258. It was first grown in 1948 and has shown very promising results since, particularly in certain areas.

Plant. The plant is upright with foliage somewhat like Katahdin but lighter in color. The flowers are white. It does not bloom too freely. In many respects it has the characteristics of the Green Mountain in that the variety performs best in the northern potato-producing areas where it is considered an early to medium early variety. In the South it would be considered a mid-season variety.

As with all oblong potatoes it does its best when the soil moisture is evenly distributed throughout the season, and therefore would perform best under irrigated conditions. However, it is not absolutely necessary, particularly in the northern section.

It will mature from 10 days to 2 weeks earlier than the Burbank.

Potatoes. The tubers are oblong and russeted. They are brighter and lighter than the Burbank. The cooking and baking quality would be rated very good to excellent, similar to that of Green Mountain.

It is medium in yielding ability, but a high percentage of the tubers would fall into U.S. No. 1's.

[1]Accepted for publication December 10, 1956.

[2]Head, Horticultural Research Department, Louisiana State University, Baton Rouge, La.

Rushmore does not produce knobs or second growths as readily as most other oblong varieties. The sprouts on the potatoes have a yellow color similar to that of Green Mountain.

It will probably perform best in the northern areas and has shown excellent performance from the Dakotas to Maine. If grown in the southern areas, the land should be irrigated or it should be grown on wider rows where the moisture supply is more or less evenly distributed.

Disease Resistance. We claim no disease resistance for plants or potatoes. Although it is a russet variety, it is susceptible to scab. Nevertheless, due to its earliness, shape and cooking qualities, those who have grown it feel that it has a definite place in the industry.

Seed. Seed of this variety may be obtained from

Dr. H. M. Darling, Department of Plant Pathology, University of Wisconsin, Madison, Wis.

Mr. Melvin Rominsky, Starks Farms, Rhinelander, Wis.

Mr. A. G. Tolaas, Director of Seed Certification, University Farm, St. Paul, Minn.

Mr. R. C. Hastings, Seed Department, State of North Dakota, Fargo, N. D.

Mr. John C. Noonan, Secretary, South Dakota Potato Growers, Watertown, S. D.

Mr. Charles S. Blackman, Clark, S. D.

Dr. Matthew Felton, Nebraska Certified Seed Association, Alliance, Nebr.

Acknowledgments

Assisting in the breeding and development of this variety were Dr. Raymon E. Webb, Horticultural Crops Research Branch, Beltsville, Maryland, formerly of this department; Dr. John R. King and Mr. James F. Fontenot, both of the Horticultural Research Department, Louisiana State University; and Mr. Ralph T. Brown, Superintendent, Plaquemines Parish Experiment Station, Diamond, Louisiana.

Other state officials and individual growers, who have assisted with the testing have been Mr. J. A. Schoeneman, Department of Horticulture, University of Wisconsin, Madison; Dr. O. C. Turnquist, Department of Horticulture, University of Minnesota, St. Paul; Mr. R. C. Hastings, Seed Department, State of North Dakota, Fargo; Mr. Charles S. Blackman, State of South Dakota, Clark; and Mr. Melvin Rominsky, Starks Farms, State of Wisconsin, Rhinelander.

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POTATO HANDLING EQUIPMENT FOR USE IN EXPERIMENTAL WORK[1,2]

D. R. Isleib and N. R. Thompson[3]

Expansion of potato research at Michigan State University has been the occasion for design of certain mechanical research aids. Ease of handling and storing a large number of small samples of potatoes, convenient periodic examination of tubers and a fast method of specific gravity determination seemed highly desirable. As a result, a storage container was built in which small (15-25 pounds) samples could be conveniently stored and handled; a picking table developed which would accommodate the periodic examination of large numbers of such samples or hill samples of breeding material; and an instrument built to hasten specific gravity determinations. The three improvements are described in the following paragraphs.

Storage Containers

Wooden containers were built for storage of the samples. Their convenient size permitted easy handling of the samples for various evaluation procedures as shown in figure 1. Sides and bottoms of the boxes were made of half-inch cedar boards, with ends and cleats of one-inch material. The horizontal cleats served as handles, and projected one-half inch above the end of the box to interlock with the bottom of the next box above. The boxes were stacked ten to twelve deep with good stability. Ventilation was provided by ¼ inch spaces between the two bottom boards and between the bottom and side boards. A three-inch opening at each side of the box also provided for air circulation and made possible withdrawal of tubers from the stacked boxes. In storage, these boxes were stacked on six-inch stands as shown in figure 2, two stacks per stand. The stands provided enough clearance from the floor so that a hydraulic hand truck could be used to lift and move a complete stack of 12 to 16 boxed samples.

Picking Table

A four-foot commercial picking table as shown in figure 3, was adapted for examination of individual samples. Samples were dumped into the hopper which pivoted to remain undumped when loaded. The hopper was manually tipped to pour the samples on the picking table rollers which moved at about ¼ foot per second. A conveniently located switch stopped the samples for examination on the table if necessary. If not, the sample progressed directly into a storage box which was placed on the shelf provided at the end of the table. If specific gravity of the sample was to be determined, the basket container used in this procedure was placed in the box and filled directly from the picking table discharge.

Specific Gravity

A number of methods are available for specific gravity determination but a direct weighing method was chosen as offering both accuracy and

[1]Accepted for publication November 1, 1956.
[2]Journal Article Number 1974, Michigan Agricultural Experiment Station, E. Lansing, Mich.
[3]Assistant Professor and Associate Professor respectively, Department of Farm Crops, Michigan State University, East Lansing, Mich.

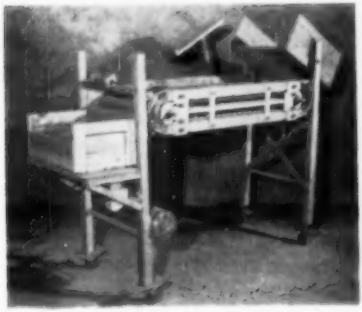

FIGURE 1.—Wooden storage box designed to hold samples of 15 to 25 pounds.

FIGURE 2.—Storage boxes stacked interlocked on stand which permitted easy mobility with an hydraulic hand truck.

FIGURE 3.—Commercial picking table adapted for examination of small samples.

FIGURE 4.—Pneumatically operated machine used for the rapid specific gravity determination of plot samples.

flexibility. A special balance, calibrated to read directly in specific gravity for samples of 2.5, 5.0, and 7.5 kilograms, was obtained. This arrangement necessitated weighing in air and in water, so the device illustrated in figure 4 was built to increase speed and reduce the effort required for this operation. Construction of the machine was planned around a 15-inch pneumatic cylinder, two short pieces of garage-door track with casters, and an hydraulic plow control. The tracks were fastened securely upright and a platform carrying a tub of water rode on the tracks. The cylinder, controlled by the valve, moved the carriage. Regulation of air pressure supplied to the valve, plus adjustment of the valve, allowed the speed of the carriage to be varied. A rubber-covered egg basket 5 inches deep by 14 inches in diameter held the sample. The use of two such baskets resulted in little time loss waiting for samples to drain or baskets to fill.

These three aids have materially reduced man-hour requirements for potato sample evaluation.

A NOTE ON THREE SORTS OF RESISTANCE TO LATE BLIGHT[1]

J. E. VAN DER PLANK[2]

This note presents no new facts. Its purpose is to show that there is clear evidence of at least three sorts of resistance in the potato to *Phytophthora infestans*; and that if stable resistance is to be found for early-maturing varieties it must be sought in directions that have hitherto been practically unexplored.

RESISTANCE OF THE FIRST SORT

This is racial resistance, conferred by genes R_1, R_2, R_3, R_4 in the international nomenclature of Black, Mastenbroek, Mills and Peterson (1). A fifth gene probably exists, and there may be more, according to Niederhauser, Cervantes and Servin (4). These authors coined the name racial resistance. It implies that these genes provide resistance against some races of *P. infestans* but not against others.

Races of *P. infestans* occur frequently. Race 1, able to attack R_1-types was found soon after these types were grown, and practically the whole range of potential races has been reported since. In *Solanum demissum*, from which these genes have been derived, Niederhauser *et al.* (4) found no clones resistant to the most highly specialized Mexican races. Very illuminating is the work of Howatt and Grainger (3) who started with race 0, against which any of the four genes confers resistance, and from it obtained in a glasshouse in a single season race 1,2,3,4, against which all four are ineffective, even in combination.

It seems implicit in the concept of racial resistance that the advantage it gives to varieties will disappear if those varieties become the most widely planted. So far, this has not been put to the test because the most widely planted varieties are still those without racial resistance: Katahdin, Russet Burbank, Cobbler, Red Pontiac and White Rose in the United States; Majestic, King Edward and Arran Pilot in England; Voran, Bintje and Eigenheimer in Holland; Brownell, Sebago and Sequoia in Australia; Up-to-Date in South Africa; and so on wherever records could be traced. But if a genotype with racial resistance alone progressed far enough to become the common genotype the races of *P. infestans* capable of attacking it would presumably become the common races, and unless there is some factor operating which is still unknown any advantage from the racial resistance alone would be lost in the wake of the genotype's progress.

RESISTANCE OF THE SECOND SORT

This is associated with late maturity, though it does not necessarily always accompany it. Some late varieties, like Robijn from Holland, can grow through quite severe epidemics without suffering much harm; they become infected, but because of their resistance or tolerance (call it what you will) infection spreads slowly and a fair crop is set despite the disease. This resistance seems to be reasonably stable and without serious racial complications.

[1]Accepted for publication October 2, 1956.
[2]Division of Plant Pathology, Department of Agriculture, Pretoria, South Africa.

The relation between resistance and lateness may be studied in Hogen-Esch and Zingstra's (2) Geniteurslijst voor Aartappelrassen. After excluding varieties with the genes R_1, R_2, R_3, R_4 (to avoid interference by racial resistance) there are 175 varieties in the list with appropriate information of which all except 3 are named commercial varieties from different countries. These are rated for resistance to blight in the foliage from 3 (very susceptible) to 9 (very resistant). They are also rated for lateness from 3 (very late) to 10 (very early). In this rating, to give examples, Irish Cobbler is 8, Chippewa 7, Sebago 6 and Robijn 3. Table 1 shows the average blight rating of all the varieties of any one lateness rating.

TABLE 1.—*Relation between resistance of the foliage and lateness. Data from 175 varieties.*

No. of Varieties	6	21	32	37	38	27	12	2
Lateness Rating[1]	3	4	5	6	7	8	9	10
Average Blight Rating[2]	8.5	7.5	6.8	5.5	5.1	4.3	4.1	3.0

[1]Low figure: very late.
[2]Low figure: very susceptible.

This sort of resistance is useful in countries to which late-maturing varieties are suited; but the degree of lateness needed for adequate resistance is too much for most potato-farming areas.

RESISTANCE OF THE THIRD SORT

In the absence of racial resistance, this sort of resistance can be inferred from the difference in susceptibility between varieties of about the same lateness rating: between, *e.g.*, Sebago and Green Mountain.

This is a sort of resistance that breeders have been busy with ever since blight struck the potato fields in the 1840's. In all probability great progress has been made, in the sense that varieties are now probably less susceptible than they were in the 1840's[3] But within the limits of the species *Solanum tuberosum* the scope for further great advance is probably limited, and no breeder (without the help of racial resistance introduced from other species) has produced an early variety with enough resistance to survive a blight epidemic successfully.

To digress, it may well be that the second and third sorts of resistance are not wholly independent of each other, and that lateness intensifies resistance of the third sort and earliness diminishes it. But this does not affect our argument in any way.

Also irrelevant to our argument are the various mechanisms of resistance: resistance to the penetration of the host by a spore, resistance to the spread of mycelium within the host after infection, delayed development of sporangia and their restricted production per unit area of lesion, *etc.*

[3]There is direct evidence of this in the varieties known to have been brought into the mountains of Basutoland in 1833. They are extremely susceptible by comparison with modern commercial varieties of similar lateness.

Other Possibilities

Two possibilities merit examination.

First, it is possible that the genes R_1, R_2, R_3, R_4, *etc.* confer not just racial resistance alone but also other resistance of an unknown sort, in which case it might be beneficial to collect as many genes together as possible. For example, $R_1R_2R_3R_4$-types may be somewhat less susceptible on the average to race 1,2,3,4 than comparable R_1-types are to race 1, and duplex R_1R_1-types somewhat less susceptible to race 1 than comparable simplex R_1-types, with triplex and quadruplex types perhaps even less susceptible. Niederhauser *et al.* (4) have indeed drawn attention to the field resistance of one duplex R_1R_1 variety. But more evidence is needed.

Secondly, there may be an untapped source of resistance of the third sort in wild tuber-bearing species like *S. demissum*. So far this resistance has been used mainly, or only, from *S. tuberosum*. Niederhauser *et al.* (4) refer to the very great field resistance, apart from racial resistance, of *S. demissum* and other wild species. Unfortunately it is not clear what sort this resistance is. Many clones of *S. demissum* are very late in maturity—they would rate less than 3 in the scale used in table 1— and one would expect much resistance of the second sort. Other wild tuber-bearing species are also often very late. Perhaps in these wild species resistance of the second sort is the safest and most common sort of field resistance, which would be unfortunate because it is necessarily inappropriate for the breeding of early varieties. One can only hope that in these species there is good resistance of the third sort as well.

Even in the absence of sound evidence for them, these two possibilities merit the attention that last hopes should get.

Summary

Three sorts of resistance are discussed.

The first sort is racial resistance conferred by the genes known in international nomenclature as R_1, R_2, R_3 and R_4. There may be others. Racial resistance is overcome by appropriate races of *P. infestans*, and the advantage from it appears to be necessarily lost in varieties that come to be the common varieties.

The second sort is coupled with late maturity. Some very late-maturing varieties, especially from continental Europe, have considerable resistance or tolerance. From its nature, this resistance cannot be transferred to early-maturing varieties.

The third sort of resistance is apparent in the difference in resistance between varieties of about the same maturity; between, *e.g.*, Sebago and Green Mountain. It seems to be inadequate in *S. tuberosum* for early varieties.

Two possibilities are discussed as last hopes for the breeding of popular early-maturing varieties with stable resistance. It is possible that genes R_1, R_2, R_3 and R_4 confer other resistance besides racial resistance. It is also possible that there is an untapped source of resistance of the third sort in wild tuber-bearing species like *S. demissum*.

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ABSTRACTS OF PAPERS PRESENTED AT ANNUAL MEETING

HEILIGMAN, F., AND J. R. WAGNER

EFFECTS OF CHLORO-IPC ON SPROUTING AND LOSSES IN WHITE POTATOES DURING STORAGE

The use of 3-Chloro-Isopropyl-N-Phenyl Carbamate (Chloro-IPC) reduced losses in white potatoes stored at 55, 72, and 85° F. when compared to untreated controls. The material was effective when used as a dip, as a spray, or when incorporated in water emulsion potato wax. The treatment controlled sprouting and reduced weight losses during storage. There is some evidence that the material may have some indirect effect in controlling losses caused by microbial decay.

HOYMAN, WM. G.

COMPARATIVE REACTIONS OF ATTACHED AND DETACHED LEAVES TO *PHYTOPHTHORA INFESTANS*

Thirty potted potato selections 6 to 12 inches in height and detached leaves from them were simultaneously inoculated with zoospores from a culture of race 0. The inoculations were made in a plastic-covered chamber at 70° F. and 100 per cent relative humidity.

The reaction of each of the 30 selections was recorded as soon as symptoms appeared and the final reading was made the eighth day following inoculation. Sporulation occurred on attached and detached leaves of 8 selections. Sporulation also occurred on the attached leaves of one selection, whereas the reaction of the detached leaf consisted of large lesions. The symptoms on both types of leaves of the 3 selections consisted of necrotic spotting. The attached leaves of 4 selections showed no symptoms, whereas the detached leaves showed definite necrotic spotting. No reaction was evident on leaves of 14 selections.

HOYMAN, WM. G.

POTATO SEED TREATMENTS WITH ANTIBIOTICS AND OTHER MATERIALS FOR PREVENTION OF BLACKLEG

Cut seed of Sebago potato has been treated the past 2 years to evaluate some antibiotics and other new materials in preventing blackleg. The 1955 treatments consisted of Agri-mycin 100 dip and dust, Captan dip and dust, Wescodyne dip, acidulated mercuric chloride dip and an Agri-mycin 100-Parzate dip. The dip treatments were for 3 minutes and the dusts were applied at 1½ pounds per 100 pounds of cut seed. Acidulated mercuric chloride was the most effective and Agri-mycin 100 dip next. None of the other treatments was satisfactory.

The 1956 treatments consisted of Agri-mycin 100 dip and dust, streptomycin nitrate-Captan dust and the following dips: catechol-Dowicide A, catechol-streptomycin nitrate, Agri-mycin 100-Parzate, Roccal, mercuric chloride, acidulated mercuric chloride, and Semesan Bel. The dip treatments were for 1 minute and the dusts were applied at the same rate as in 1955. Mercuric chloride, acidulated mercuric chloride and Semesan Bel were more effective than the other materials in reducing blackleg.

HOYMAN, WM. G., AND JACK R. WALLIN

INFLUENCE OF AIR-TEMPERATURE MAXIMA ON THE SURVIVAL OF *PHYTOPHTHORA INFESTANS* IN POTATO LEAVES

During 1954 and 1955, *Phytophthora infestans* appeared in potato fields at Scottsbluff, Nebraska, despite several successive days of temperature maxima between 97 and 107° F. An isolate was obtained from a tuber grown at these temperatures. Experiments were designed to compare 2 subcultures (SB and 105) of this isolate 1 from a North Dakota tuber, isolate 104 from Hollandale, Minnesota, and monozoospore subculture 35 from 1.

In 5 trials where the inoculated Red Pontiac plants were subjected to gradual temperature rises to 83, 95, 105, 108 and 114° F. for ½-1 hour, 12 hours after inoculation, all cultures produced conidia after exposure of the inoculated plants to 105°F. and below. In another trial, only culture 1 produced conidia after exposure of plants to 106° F. 15 hours after inoculation. Cultures 1 and SB were the only cultures to produce conidia when the plants were exposed to 106°F. 16½ hours after inoculation. All cultures produced conidia when the plants were exposed to 102 and 106°F. 19 and 23 hours, respectively, after inoculation. Only culture 1 produced conidia when the plants were exposed to 110°F. 23 hours after inoculation. In all instances where conidia were not produced, the presence of necrotic spots on the leaves was evidence that infection had taken place.

ISLEIB, D. R.

THE EFFECT OF GAMMA IRRADIATION ON SUBERIZATION AND PERIDERM FORMATION IN POTATO

The effect of gamma irradiation on suberization and periderm formation at levels from zero to 200,000 rep were studied with several intervals elapsed between irradiation and wounding. In all cases suberization was delayed following irradiation, but the suberized layer of treated potatoes was ultimately as thick as that of controls. All levels of irradiation studied (as low as 1500 rep) prevented the formation of periderm.

ISLEIB, D. R., AND N. R. THOMPSON

POTATO HANDLING EQUIPMENT FOR USE IN EXPERIMENTAL WORK.

Several mechanical aids designed to facilitate handling of potato samples from experimental plots have been developed, including storage containers, a special picking table, and a machine to speed specific gravity determinations. These aids have materially reduced man-hour requirements for potato sample evaluation.

JOHANSEN, ROBERT H.

FIELD RESISTANCE OF THE POTATO SELECTION ND 457-1 TO VIRUS Y

The purpose of the study was to determine the degree of field resistance to virus Y possessed by the potato selection ND 457-1, and to determine the incidence of virus Y in tubers harvested from infected plants.

The selection ND 457-1 was grown in the field for the first time in 1945. Tests conducted by this station revealed that ND 457-1 possessed a degree of field resisance to virus Y. On several subsequent occasions it was planted in fields where the current season infection of virus Y was abundant in other selections and varieties but in only a few instances were virus Y symptoms observed on ND 457-1.

Although it was known that ND 457-1 possessed this type of field resistance to virus Y no study had been undertaken to determine the degree of resistance. In order to evaluate this selection it was necessary to compare it with a standard susceptible variety. Red Pontiac, the most common variety grown in North Dakota, was chosen as that standard.

ND 457-1 and Red Pontiac were grown in each of 2 plots. As a source of field inoculum for transmission of virus Y by aphids, the virus Y carrier ND 530 was planted within each plot.

Results from this test revealed that in comparison to the susceptible variety Red Pontiac, ND 457-1 possessed a high degree of field resistance to virus Y. This test also revealed that ND 457-1 possessed a factor that delayed the movement of virus Y within the plant.

KNUTSON, KENNETH, AND CARL J. EIDE

SPORANGIAL GERMINATION AND INFECTION BY ISOLATES OF *PHYTOPHTHORA INFESTANS*

Sporangia of isolates of *Phytophthora infestans* differ widely in speed and final percentage of germination, the differences being greater at 10° and 15°C. than at 20° and 25°C. At the higher temperatures there is little additional germination after 4 hours. When potato plants are inoculated with sporangia in the greenhouse at approximately 20°C. the first appreciable infection occurs about 4 hours after inoculation. Thereafter the number of infections per plant increases with time, there being big differences in the seed of infection by different isolates. Such differences are found between isolates of the same or different pathogenic races. The differences in rate of infection do not seem associated with differences in rate of germination. The ratio of infections to concentration of sporangia in the inoculum suspension is fairly constant tends to obscure differences between isolates; too few, increase the sampling error.

KRANTZ, F. A., CARL J. EIDE, FLORIAN LAUER, AND KENNETH KNUTSON

BREEDING FOR FIELD RESISTANCE TO LATE BLIGHT

Potato clones with R_1 and R_2 genes for immunity from late blight were selected at random from selfed and backcrossed progenies. These clones, and others with no R immunity genes were inoculated with *Phytophthora infestans* in the field. Races 0(A); 1,4(BD); and 2,4(BC) were used in 1955, and only 1,4 and 2,4 in 1956. Resistance was measured by the amount of green foliage remaining at successive intervals after inoculation.

Forty days after inoculation, different clones in the R_1 and R_2 groups had retained from 0 to 70 per cent of the foliage; in the R_1 group 0 to 60 per cent was retained. The resistant R_1 and R_2 clones were simplex and mostly early. Among the clones having no immunity genes most of the field resistance ones were very late; Red Pontiac being the earliest with any appreciable amount of resistance. However, some of the late-maturing clones were defoliated as quickly as the early ones suggesting that lateness as such is not the basis of field resistance in these clones. The availability of early clones with both immunity genes and field resistance, apparently offers the most immediately feasible means of securing both field resistance and earliness. The possibility still exists, however, that early clones with field resistance but no immunity genes can be developed.

LAUER, F. I., AND F. A. KRANTZ

FORMATION OF CALLUS TISSUE WITH NEW GROWING POINTS AND BUDS IN THE POTATO

Callous tissue formed only on the stolen side of vertical slices, cut across the apical eye-stolen end axis of non-dormant tubers with eyes removed were placed in moist sand for five months at room temperature. Callous tissue was also obtained on the exposed portions of roots and on the cut surfaces of seed pieces and stems of plants from which all buds had been removed for three to four weeks. With the exception of roots, callous formation occurred only on the basal side of cut surfaces which exposed the vascular system. Subsequently, growing points developing into buds occurred on some of the callouses on the stems, seed pieces and roots. Scar or wound periderm formation appeared prior to callous formation indicating a different growth process which may not involve cell division.

LOGSDON, CHARLES E.

THE EFFECT OF CERTAIN ANTIBIOTICS ON POTATO PRODUCTION AND RING ROT CONTROL IN ALASKA

Seed treatment of ring-rot-inoculated potatoes with Agrimycin-100 (15 per cent streptomycin and 1.5 per cent oxytetracycline) reduced the percentage of hills with symptoms at harvest from 39.2 to 8.0 when used at a concentration of 1000 p.p.m. Agritracin (5 gms. bacitracin per pound) had no significant effect. An additional 34.8 per cent of the Agrimycin treated hills were found infected, when examined after storage. This amount was significantly less statistically than the untreated check. Seed

treatment of uninoculated potatoes with Agrimycin-100 at 5000 p.p.m. reduced yields from 7.5 to 3.2 tons per acre. This reduction was due to decreased stand, a smaller percentage of U. S. 1A size and the smaller size of the U. S. 1.

MCANELLY, CHARLES W.

A STUDY OF POTATO SPINDLE TUBER BY PAPER CHROMATOGRAPHY

Selections of normal-appearing and spindle tuber-infected tubers of a potato seedling were selected at digging time. The eyes of each tuber were removed, placed in separate Petri dishes and frozen quickly. After thawing, the juices were extracted and used for one and two dimensional ascending chromatograms. Determination of the amino acids and protein patterns were then made and compared. An apparent increase in certain amino acids and protein fractions was noted in the spindle tuber infected tubers.

MILLS, W. R., JOHN S. NIEDERHAUSER, AND R. W. HOUGAS

BLIGHT RESISTANCE OF SELECTED SOLANUM HYBRIDS IN MEXICO

Crosses were made between clones of *Solanum demissum* (hexaploid) selected for high resistance to *Phytophthora infestans*, and 15 blight-susceptible diploid *Solanum* spp. Resulting F_1 hybrids were backcrossed to *S. tuberosum* var. Katahdin, and *S. stoloniferum*, a tetraploid species exhibiting moderate blight resistance in Mexico. A total of 110 F_1 selections, 69 Katahdin backcrosses and 50 *S. stoloniferum* backcrosses were planted at Toluca, Mexico; 4 tubers per selection. Using a rating of 0 (no blight) to 5 (plants killed), blight readings were made in July and August. None was immune. High resistance (rating of "1" or "2") was noted in 66 per cent of the F_1 selections. Progeny of the F_1s backcrossed to Katahdin were mostly susceptible, 84 per cent being rated "4" or "5". Nine per cent were rated "2" and none rated "1". Backcrosses with *S. stoloniferum* were about as resistant as the F_1 parents, and in several instances, resistance was enhanced. In addition to the above material, 64 clones of *S. andigenum* were all susceptible with ratings of "4" and "5".

MUNRO, J.

GREY BLOTCH — A VIRUS DISEASE OF SOLANACEA

A virus disease of solanaceous plants is reported. The virus causing this disease was found in a potato seedling that was showing a vague mottle. Mechanical inoculations to young White Burley tobacco plants produced symptoms which when fully developed, seemed to the casual glance to be mechanical damage. The symptoms developed as irregular rings, half rings, or as was most usual, shapeless blotches that coalesced, and showed first on inoculated, and then on uninoculated leaves. The blotches were interveinal and appeared to be caused by destruction of the mesophyll tissue. Similar symptoms developed in *N. glutinosa* and other *Nicotiana* spp. without any other apparent symptoms. However, in *Physalis pubescens*, and *P. angulata*, the plants were also dwarfed and the leaves distorted.

Inoculations to potato varieties and seedlings caused only a vague mottle on some and occasionally brown leaf necrotic patches on others. But when this virus was inoculated to plants of these varieties and seedlings already infected with virus X, a synergistic effect was invariably produced causing numerous severe necrotic blotches on the leaves.

Aphid transmissions have not been obtained. Immune rabbit anti-serum to this virus has been produced.

RICH, A. E., AND R. F. BECKER

THE EFFECT OF IRRADIATION AND OTHER TREATMENTS OF POTATO TUBERS ON PLANT GROWTH AND VIRUS CONTENT

Green Mountain potato tubers known to be infected with one or more viruses were halved, and half of each tuber was irradiated for a period varying from 3 hours (3.08×10^{12} neutrons) to 12 hours (1.31×10^{13} neutrons). Both halves of each tuber were planted and data on growth and virus symptoms were recorded. Irradia-

tion reduced emergence and plant growth but had no apparent effect on leafroll, mild mosaic or rugose mosaic in the plants that survived. There was some evidence that the latent mosaic virus (virus X) was reduced or weakened. Papain applied to tubers and growing plants did not inactivate virus X, although it appeared to weaken it. Ultrasonic treatment of potato juice extracts failed to inactivate virus X in preliminary trials.

RIEMAN, G. H., W. J. HOOKER, F. A. KRANTZ, AND H. O. WERNER

POTATO IMPROVEMENT THROUGH PARENTAL LINE BREEDING

The asexually propagated clones now being used in potato breeding programs are genotypes which segregate more or less for most, if not all of their important characters. This means that there are hundreds of genes influencing these characters and segregating in each cross. With only 20 genes segregating in a cross slightly over a million combinations are possible. A population of around 5 million is likely to be required in order to be reasonably sure that the desired character combinations will appear at least in one individual plant. The production of parental lines possessing high homozygosity for one or several desirable characters will be of great value since the size of populations necessary for screening will be reduced and the time required for the production of new varieties will probably be shortened. The improvement of the best existing parental clones by inbreeding is suggested, *i.e.* by crossing clones with similar characters of different genetic origin, sib mating, selfing, or various combinations of these methods.

SCHUSTER, M. L., G. T. STACHWICK, AND R. E. HILL

PENTACHLORONITROBENZENE AN EFFECTIVE CONTROL OF COMMON SCAB AND OTHER PESTS OF THE POTATO IN NEBRASKA

Field tests in western Nebraska during the 1953-1956 period indicate that pentachloronitrobenzene (Terraclor) can effectively control common scab (*Streptomyces scabies* (Thax.) Waks. & Henrici.), tuber flea beetle(*Epitrix tuberis* Gentner) and black scurf (*Rhizoctonia solani* Kuhn). The appearance of the tubers is considerably improved due to control of these tuber diseases, as well as the russeting found commonly on untreated lots. This chemical also has weed control properties. The residual effect with low rates of application were but slight and temporary on crops grown in rotation. Our yield data emphasize positive weed control. Although PCNB evinces a manifold effect, to be feasible on a commercial scale it will have to be applied in bands to decrease the amount of chemical necessary. Certain defects in the present machine used will be explained and a more desirable type suggested.

SCHWIMMER, SIGMUND, HORACE K. BURR, W. O. HARRINGTON, AND WILLIAM J. WESTON

GAMMA IRRADIATION OF POTATOES: EFFECTS OF SUGAR CONTENT, CHIP COLOR, GERMINATION, GREENING, AND SUSCEPTIBILITY TO MOLD

Russet Burbank potatoes that had been stored at 40°F. for 5 months after harvest were irradiated with 5200 and 14,000 rad. of Co^{60} gamma rays. In general, irradiation caused an accumulation of sugars. At 40°F., the sucrose level rose to nearly 3 times that of the control in 16 days following irradiation. Fructose and glucose showed smaller increases and the latter did not accumulate significantly in the tubers given the higher dose of gamma rays. At 70°F., the levels of sucrose and glucose in the irradiated tubers rose above those in the controls, the difference reaching a maximum in 4 days and then declining. Irradiation had no effect on the loss of fructose at this temperature. Color of potato chips processed from the irradiated potatoes was in general darker than that of chips from control tubers. The storage-time pattern of color change resembled that of the reducing rather than total sugar. Fourteen thousand rad did not prevent initiation of germination in the tubers but did destroy their sprout-growth apparatus. Although the lower dosage did not prevent initiation and subsequent growth, it prevented the formation of

secondary tubers, which appeared on the sprouted control tubers. Furthermore, unlike the controls, the low-dosage potatoes developed branching hair sprouts with no tendency toward apical dominance during the early stages of sprouting. The rate of greening of gamma-irradiated and illuminated tubers was significantly less than that of unirradiated illuminated controls. Evidence is presented that irradiation may increase the susceptibility of potatoes to attack by molds under some conditions.

SHEALY, ROBERT D.

STEM ROT DISEASE OF IRISH POTATO

In 1955 a stem rot disease of Irish potato was severe in Ohio. Apparently, above ground plant parts are invaded by the pathogen but decay may extend into the roots. A bacterium was isolated repeatedly, in 1955, from diseased tissue and incited the disease on plants in the field and greenhouse. Tubers were planted in soil collected in early March 1956 from fields in which the disease had been severe in 1955. Symptoms of the disease developed on plants growing in this soil in the greenhouse. The morphological and cultural characteristics of the pathogen are similar to non-gas forming species of several plant pathogens which cause soft rots of many vegetables, yet the pathogen does not fit the exact description of any species.

SMITH, ORA

EFFECT OF CULTURAL FACTORS AND MATURITY ON SUGAR CONTENT AND SPECIFIC GRAVITY OF POTATOES AND COLOR OF CHIPS

Potatoes were grown (1) with and without irrigation, (2) DDT sprays all season *vs.* DDT in all but last 3 sprays *vs.* no DDT, (3) nitrogen spray applications once a week *vs.* no nitrogen added after planting, (4) several methods of vine killing and (5) maturity at harvest. Potatoes were harvested at weekly intervals from August 15 to October 3 and on October 29. Potatoes were stored at 40°F. and fried at three storage intervals. Reducing sugar content was determined on day of harvest and after 6-7 months storage.

Differences in specific gravity, sugar content and chip color were found between a number of the treatments.

SMITH W. L. JR.

DECAY, SURFACE BROWNING, SCALD, WEIGHT LOSS, AND CHIPPING QUALITY OF EARLY-CROP POTATOES AS AFFECTED BY STORAGE TEMPERATURES

Eight replicates of early-crop potatoes (Irish Cobbler and Sebago) from southeastern United States were held at 40°, 50°, 60°, 65°, 70°, 75°, and 85°F. for 60 days or longer. Decay developed most rapidly and was most serious on tubers stored at 85°. At 70° or 75° decay was relatively unimportant until the tubers had been stored 25 or 40 days. At 65 it was considerably less than at higher temperatures. At 40°, 50°, and 60° little or no decay developed. Storage temperature did not appreciably affect the development of surface browning, but scald was less at 40° and 50° than at higher temperatures. Production locations and tuber exposures after digging affected the amounts of decay, surface browning and scald. Weight loss, except that caused by decay, was more in potatoes stored at 85°, and somewhat less in those at 40° and 50°, than in those stored at other temperatures. It did not differ appreciably in lots stored at 60°, 65°, 70° and 75°. Chipping quality of potatoes stored at 70°, 75° and 85° was satisfactory for 60 days. The chips were darker when lower storage temperatures and longer storage periods were used.

SMOOT, J. J., F. J. GOUGH, AND M. E. GALLEGLY

OOSPORE FORMATION IN *PHYTOPHTHORA INFESTANS*

Oospores were consistently formed in abundance when any one of three isolates of *P. infestans* from Mexico was paired with any of more than 100 isolates from the British Isles, Western Europe, Africa and North America. A fourth isolate from Mexico formed oospores only when paired with the other three Mexican isolates. All isolates were pure cultures of *P. infestans* pathogenic to potato. There

was no correlation between the physiologic race and the mating reaction. Oospores formed between the two cultures soon after the juncture of the two mycelia, and later involved a much wider area throughout a 3 mm layer of media. As many as 250 oospores were observed in a single focal plane of a 1.5-mm-diameter microscope field. This is in contrast to the low numbers occasionally formed with single cultures or with intra-group pairings. Paired cultures formed oospores in liquid, agar, or gelatin media fortified with extracts of frozen lima beans, dried soybeans, or other natural materials. Oospores were formed also in the leaves of 16 varieties of potato and one variety of tomato following paired inoculations where the variety was susceptible to both parent strains. Mature oospores varied in diameter from 24 to 56 and in color from pale yellow to dark brown, depending upon the medium.

STEINBAUER, G. P.

INTERACTION OF TEMPERATURE AND MOISTENING AGENTS ON THE GERMINATION AND SEEDLING DEVELOPMENT IN THE POTATO (*SOLANUM TUBEROSUM*)

Seeds of the potato were germinated on top of blotters in petri dishes, using either water or 0.2 per cent KNO_3 as moistening agents. Temperatures used were constant 5°C., 10°C., 15°C., 20°C., 25°C. and 30°C. and alternating 20°C. (16 hrs.) and 30°C. (8 hrs.). The above treatments were also used following treatment of the seeds with thiourea and sulfuric acid. Eight different lots were tested.

Only two of the lots showed significantly higher germination with nitrate than water. However, all lots gave a marked increase in stem (hypocotyl) length when nitrates were used in place of water. This resulted in a higher stem/root ratio in the seedlings. The optimum temperature, regardless of moistening agent was 20°C. Results with thiourea were negative. Pre-treatment with sulfuric acid resulted in increased rate of germination but the tendency of mold render the method of doubtful value.

THOMPSON, N. R., AND D. R. ISLEIB

TEMPERATURE-GROWTH RELATIONS: I. SPROUTING

Emergence of potatoes at various soil temperatures was studied to determine optimum planting time in the field. Growth was slow at soil temperature of 50°F. or below, but at 52°F. or above there appeared to be little difference in rate of sprout or root growth. Slight varietal differences were noted.

THURSTON, H. DAVID, CARL J. EIDE, AND KENNETH KNUTSON

THE EFFECT OF LOCATION AND RACES ON THE EPIDEMIOLOGY OF *PHYTOPHTHORA INFESTANS*

The spread of *Phytophthora infestans* on potatoes in a plot on upland silt-loam soil was compared with that on low-lying, peat soil during 1952-1954 inclusive. A single plant in the center of each plot was inoculated. Judged by the presence of late blight lesions, the fungus generally spread from one plant to an adjacent plant instead of at random over the entire lot. Two or more distinct spreads always occurred before all of the plants in a plot (56 x 125 ft.) were infected. Weather data in 1953 and 1954 indicated more periods favorable for sporulation and reinfection in the plot on peat than that on the silt loam. As expected the fungus spread more rapidly in the peat plot. Although there were slightly more favorable periods on the peat plot in 1952, the fungus spread more rapidly in the silt loam plot. Smaller plants and consequently better aeration in the peat plot afford a possible explanation for this. In 1954, 2 identical lots on silt loam only 400 ft. apart were inoculated with races 1 and 0, respectively. Race 0 spread much faster than 1, indicating that it may be the more aggressive of the two.

WALLIN, JACK R., AND DALE N. POLHEMUS

THE INFLUENCE OF TIME AND TEMPERATURE ON SPORULATION OF *PHYTOPHTHORA INFESTANS* ON POTATO LEAVES

The quantity of sporangia produced by several isolates of *P. infestans* on potato leaflet lesions at 6 different temperatures (60, 65, 70, 75, 80 and 85°F.) and at 4

time periods (6, 8, 10 and 12 hours) was estimated. Droplets of aqueous suspensions of sporangia of the isolates were placed 1 droplet per leaflet on Russet Burbank potatoes the same age. The plants were incubated in a moist chamber 15 hours at 65°F. Then, the plants were removed to the greenhouse bench and held until lesions about 1 cm. in diameter developed. Sets of 8 plants bearing such lesions were placed in a dew chamber at each of the above-mentioned temperatures and were removed in pairs after 6, 8, 10 and 12 hours. Lesions were collected and sporangia counts were made. At 60°F. none of four isolates sporulated after 8 hours. The quantity of sporangia produced by all isolates increased with time but the quantity of increase varied among isolates. At 70°F., three of four isolates sporulated in 6 hours; one weakly and two moderately. Two isolates sporulated 2-3 times more abundantly after 6 hours. One isolate produced 400 times more sporangia after 12 than after 10 hours. At 75°F., 2 of 3 isolates sporulated in 6 hours. The quantity of sporangia produced by these isolates increased with time.

WEBB, R. E., AND E. S. SCHULTZ

A TEST FOR RESISTANCE TO VERTICILLIUM WILT IN POTATO

Selection of Verticillium-wilt-resistant potato seedlings has proved highly feasible under greenhouse conditions. Seedlings are grown in sterilized soil and at the transplant stage are lifted and the roots are washed free from soil. The roots are momentarily immersed in a blended 12-day-old solution culture (potato dextrose) of a virulent isolate of *Verticillium albo-atrum* Reinke & Berth. Inoculated plants then are transplanted to sterilized soil in 3-inch pots and kept at greenhouse temperatures regulated at 65-70°F. Wilt-susceptible seedlings usually develop symptoms 12-30 days after inoculation, the period depending upon their parents. Resistant seedlings are allowed to tuberize and are harvested for selection under field conditions. Approximately 95 per cent of wilt-resistant seedlings selected in the greenhouse have not developed symptoms when planted in soil heavily infested with the wilt organism. Clonal selections have been similarly evaluated for wilt resistance by germinating eyes removed from the tuber with a melon scoop and using the inoculation technique described. Isolates highly pathogenic to the resistant potato variety Houma have not been isolated. The fact that isolates highly pathogenic to Verticillium-wilt-resistant tomato varieties have been found indicates that they may exist.

WEBB, R. E. AND E. S. SCHULTZ

INFLUENCE OF TEMPERATURE AND DAYLENGTH ON DIAGNOSIS OF IMMUNITY FROM VIRUS X IN POTATO

Formation of aerial tubers on scions of Green Mountain plants grafted to stocks of X-immune seedlings 41956 is used as a criterion of immunity from Virus X. Environmental conditions greatly affect the efficiency of this technique. Plants of Green Mountain were approach-grafted to plants of 41956, and 16 of each were placed under daylengths of 8, 12 and 16 hours at 65-70°F. A similar number of such plants were held at 70-75°F. under 12- hour day .The base of each Green Mountain plant was severed just below the graft 12 to 14 days after grafting, and the plants of 41956 were removed slightly above the graft. Under the 8-hour day, 15 of 16 scions developed large axillary tubers aproximately 25 days after grafting. Only 2 scions developed aerial tubers under the 12-hour day, and 0 under the 16-hour day. Under the 12-hour day 6 scions and under the 16-hour day 7 developed enlarged nodes and axillary buds during a similar period. Plants not producing aerial tubers or enlarged nodes and axillary buds wilted slowly because of deterioration of rootstocks. All plants held at 70-75°F. wilted rapidly and died. A similar series in which 41956 was used as the scion and subjected to the conditions described produced plants that did not form aerial tubers or wilt.

WRIGHT, N. S.

STRAIN INTER-ACTION OF POTATO WITCHES' BROOM VIRUS

Three strains of the potato witches' broom virus are readily distinguishable by the symptoms induced in tomato (var. Bonnie Best) and *Cyphomandra betacea* (tree tomato). Multiple strain inoculations made by grafting to tomato, *C. betacea*, and potato revealed that cross protection does not occur between strains of this virus. On

tomato a composite syndrome developed indicative of the strains involved. On *C. betacea*, inoculation with any strain complex involving strain 2 caused symptoms which were typical of strain 2 infection and simultaneous inoculation with strain 1 and strain 3 resulted in symptoms which were typical of strain 1 infection. However, grafts from the infected *C. betacea* to tomato resulted in the development on tomato of the complex syndromes indicating that masking and not cross protection had occurred. On potato (seedling 41956) the symptoms caused by each strain and strain complex were indistinguishable, but when grafts were made from potato to tomato, the strain or strains infecting each potato could be identified by the symptoms on tomato.

YOUNG, ROY A., AND W. J. TOLMSOFF

CULTURAL AND CHEMICAL TREATMENTS FOR CONTROL OF THE EARLY MATURITY DISEASE OF POTATOES

The early maturity disease of potatoes annually reduces yield on several thousand acres in south central Oregon. *Verticillium albo-atrum*, the principal cause of disease, can be isolated from vascular tissues throughout diseased plants. *Fusarium* and *Pythium* spp. can be isolated from roots, and a series of *Colletotrichum* frequently can be isolated from crowns of diseased plants. The disease, which is most severe on light, sandy soils, was reduced in severity but not effectively controlled by applying optimum quantities of nitrogen fertilizers, by crop sequences involving cereals as a preceding crop, and by seed-piece treatment with dichlore or Semesan Bel. Although the above procedures contributed to reduction of the disease, they are not sufficiently effective to produce a good yield of potatoes. For that reason several chemicals have been tested as soil fungicides for control of the disease. Soil treatment with 190 pounds of Vapam per acre was extremely effective in 1955. When land treated in 1955 was replanted to potatoes in 1955, residual effects of the treatment were apparent in both disease control and weed control. In dosage rate trials in 1956 a significant degree of control was obtained with rates as low as 40 pounds of Vapam per acre.